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TECHNICAL NOTES.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

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No.15.

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TESTS OF THE DAIMLER D-IVa ENGINE AT A HIGH  
ALTITUDE TEST BENCH.

By

W. G. Noack.

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Translated from  
Technische Berichte Vol. III - Sec 1,

by

Paris Office, N.A.C.A.

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The following translation was made by the Paris Office of the National Advisory Committee for Aeronautics in view of the general interest that has been evidenced in connection with numerous engine tests conducted for the National Advisory Committee for Aeronautics in the Altitude Chamber of the Bureau of Standards, the results of which have appeared in the Committee's reports.

With a view to investigating the power decrease of a 260 H.P. Daimler engine at altitudes, and the behavior of that engine when fresh air is inducted, tests were made at the high altitude test bench (vacuum chamber) at Friedrichshafen from November, 1917, to February, 1918. The last few tests were specially intended to decide what increase of power may be gained and what conditions of work are realized when fresh air is supplied to the engine through a blower. The present author first made the proposal in January, 1917, that normal aircraft should be equipped with a centrifugal blower for that purpose and that it should either be directly coupled or - especially in the case of giant airplanes with several engines - be worked by the main shaft or by a special engine.

The vacuum chamber, which enabled the above-mentioned tests to be made on the ground under conditions considerably like those at a certain altitude, was lent for the purpose by the Zeppelin Aircraft Works at Friedrichshafen. The inbuilding of the engine and the entire preparations and measuring gear were taken care of by the Experimental Department of the Zeppelin Works, under the direction of Engineer Leitmann, whose invaluable support and collaboration are hereby gratefully acknowledged. The engine was furnished by the Rea Equipment Depot



at Doberitz. The idea of supplying fresh air by external pressure, or by means of a blower, originated with the present writer, as also the alterations entailed, in consequence, in the engine and in the fuel supply. The centrifugal blower was one of those intended to be mounted, by way of experiment, in the 1000 H.P. giant aircraft. It was constructed by Brown, Boveri & Co., in close collaboration with the writer.

#### I. THE VACUUM CHAMBER.

The vacuum chamber of the Zeppelin Dirigible Works at Friedrichshafen is constructed for the purpose of experimenting on engines and radio equipment with regard to their suitability for high altitudes, and also for investigating the adaptability of the crew in that respect.

It consists of a ferro-concrete building with a ground area of 8.5 by 4 sq.m., 3.4 m. at its highest pitch. A vacuum is created in the chamber by an ENCKE'S positive blower driven by electric power. The pressures are obtained by means of two automatic regulating valves which are subsequently replaced by an ordinary stop-valve. The exhaust gases are taken off through a capacious passage, where they are cooled by running water and exhausted by the positive blower. The test chamber communicates with the exhaust passage by small, adjustable orifices, so that there is equal pressure in both. The engine-power is measured by a water-brake, the fuel consumption by a calibrated measuring recipient. When the power is furnished by outside air and blowers, the fuel is weighed. The number of revolutions is recorded by an ordinary aircraft tachometer, and its work is repeatedly checked by a hand-tachometer. The temperature of the cooling water is regulated by the addition of fresh water. The exhaust pipes, and afterwards the under-side of the crankcase were cooled by means of water sluicing to enable duration tests to be made. The cooling water for engine and brake is likewise removed by means of a positive blower driven by electricity.

The chamber is provided with double doors and a sluice, thus supplying a means of exit when vacuum prevails in it. A dial telegraph serves as a means of communication from the inside of the chamber to the outside. As the centrifugal blower must be installed outside the vacuum chamber, orders are passed on by flash signals.

When a 260 H.P. engine is working and taking in its fresh air from the chamber, about 340 mm. mercury absolute, corresponding to an altitude of about 6500 m., may be maintained. If the whole of the fresh air for the engine be permitted to flow in from the outside, about 450 mm. mercury absolute only (about 4500 m.) can be attained. When tests were made in extremely rarefied air, the workers wore oxygen masks, and a large flask of oxygen is always kept in the chamber, near the fire grenades, for use in case of emergency.

It may here be mentioned that the chamber, in its present condition, is the result of long and costly experiments. Considering that it would scarcely be worth while for the majority of aviation engine manufacturers to construct altitude benches of their own, though future needs will make



it urgently advisable to investigate engines with regard to altitude requirements, the Zeppelin Dirigible Works have offered their vacuum chamber and its measuring installation, for rent for such purposes.

## II. THE ENGINE AT DECREASING ATMOSPHERIC PRESSURE.

The D. IVa engine, No.29609, was mounted on the test-bench for investigation, without any alterations. For the first series of experiments, fresh air was taken in from the experimental chamber and inducted through the air-passage of the crankcase in the usual manner. The engine ran with light gasoline,  $\gamma = 0.708 \text{ kg/dc}^3$  at  $15^\circ\text{C}$ . The time of consumption for every 3 dec.<sup>3</sup> was registered by a stop-watch, the pressure in the chamber by two dirigible barometers. Whenever a variation in pressure was caused by the opening or closing of the regulating pressure valves in the chamber, normal regime conditions were set up and each reading was repeated several times. The powers were fixed for 1450 and 1550 r.p.m. alternatively.

The results of these tests are collectively given in Table 1. The same values, in terms of altitude, are shown in Fig. 1 (measured on the dirigible barometer), and in Fig. 2 in terms of atmospheric pressure (Curve 1).

There is a striking decrease of power at high altitudes. The tests were consequently made under altered conditions. The fresh air was again taken from the experimental chamber, but it was no longer inducted to the crankcase by the passage, being directly injected into the carburetor. Table 2, and the plotting of curve 2, Figs. 1 and 2, show that the powers resulting on this occasion were considerably higher and the consumption lower, and the explanation of this must be sought for in the different temperatures of the inducted air. The temperature of the air directly in front of the carburetor was not, unfortunately, measured at the first test, but we may safely assume that the air is heated to some extent by passing the hot crankcase; the more the atmospheric pressure decreases, and the mass of air in consequence, the more heated does the air become. As the crankcase was cooled by the intake air alone, during the first tests, it became hotter and hotter in proportion to the duration of the test and the decrease of atmospheric pressure, and this again increased the heating of the air still more. There was also a difference in the temperature of the air of the chamber from which the engine inducted air for the two tests: it amounted to  $16^\circ$  to  $20^\circ$  at the first test and  $12^\circ$  to  $14^\circ$  at the second.

If it were necessary to draw a conclusion from these tests as regards conditions during flight, the effect of temperature on the power or charging coefficient would have to be known, as also the chemical and thermal efficiency of the engines. Up to the present time, it was generally considered that the power might be set down in terms proportional to the temperature of the outer air. This supposition is sufficiently accurate so long as the differences in question are slight, but if the air becomes strongly heated on the way to the intake valve, it is only the temperature in front of the intake valve that can be taken as a standard. The dependency of the power on the temperature of the outer air, as resulting from a



number of later tests with the D Iva engine, is shown in Fig. 3, which thus gives an approximate idea of the power curves at different temperatures with increasing atmospheric pressure.

The outside temperatures are here marked beside the test points, and the number of the test is also stated, in brackets. Although the values for higher and lower temperatures are distinctly different, these tests by no means suffice for the establishment of a perfectly faultless standard, owing to the fact that other variable factors enter into account in the above-named combination of test values, and that their influence on the engine power has not yet been explained and cannot, in consequence, be suppressed. These factors are, above all, the increase of temperature of the air, which varies with the density of the air and the temperature of the cooling water and affects the efficiency of the carburetor; and also the effect of differences between the intake and exhaust back-pressure.

Fig. 3 gives positive proof, however, of the fact that the engine still functions perfectly with an air temperature of  $0^{\circ}$  in front of the carburetor, and that it attains its highest power with very slightly increased fuel consumption, (see Table 3). Considering that the air is cooled from  $20^{\circ}$  to  $25^{\circ}$  - according to the richness of gasoline in the mixture - through the evaporation of the gasoline, it must be assumed that the carburetor heating, the warmth of the burnt gases remaining in the cylinder, the compression and the hot walls of the cylinder and valve suffice to evaporate the fuel. We must here observe that the intake pipes were thickly covered with ice during the tests, although the temperature of the surrounding air was  $+10^{\circ}$  or more. In the airplane, the air was always inducted through the engine casing and was thus warmed again. By this means, the air should seldom reach the carburetor colder than in the tests in question, even in the case of the lowest temperatures, while the formation of the mixture and the burning should be faultless with sufficient carburetor heating.

Although there may be little difference between the conditions for actual airplanes and for tests, it appears to be desirable that a mean power curve should be plotted for various flying altitudes, in proportion to the absolute temperature, Curve 3, Fig. 1. It was assumed, in this case, that the air in the crankcase passage had been heated to  $20^{\circ}$ . The mean annual temperatures given by the Wagner Meteorological Tables for corresponding altitudes were taken as the temperatures of the air.

In establishing engine power for a given altitude, consideration must be given to the fact that such engine power is practically dependent on the atmospheric pressure, which may, however, vary greatly at a given altitude in the course of a year. More accurate values may therefore be deduced from the power curve if the powers be expressed in terms of atmospheric pressure, and the temperature and atmospheric pressure, at the altitudes in question, be calculated at a given time. Fig. 2 shows the powers in terms of pressure, and Fig. 4 represents tests 1 and 2 with the Daimler engine, the number of the tests being also set down. The upper curves are those of the same powers calculated at 760 mm. barometric pres-



sure and  $15^{\circ}$  as induction temperature, according to the well-known formula:

$$N_r = N_0 \cdot \frac{760}{b} \cdot \frac{273 + t}{288}$$

If the engine power were merely proportional to the pressure, that is, to the pressure and absolute temperature of the outside air, the above curves would result in horizontals. The rapid decline of the curves as compared to the straight lines, provides a standard for the "altitude characteristics" of the engine. In the tests in question, this rapid decline is due to the heating of the intake air. The hotter the crank-case becomes, and the lower the pressure, the greater is the influence on the efficiency of the engine.

The inadequate working of the carburetor is another factor, though influencing it in a secondary degree. It has been previously stated\* that the supply of fuel in the carburetor diminishes less, with increased altitude, than the weight of air taken in with every stroke of the propeller. The result is an over-rich mixture, in which a large proportion of the fuel leaves the cylinder in an unused state and is consumed outside as exhaust flame. The thermal efficiency of the circulation is thereby considerably lowered, as may be seen from the increased specific fuel consumption represented in Tables 1 and 2. Improvement in this respect might be obtained by the use of a carburetor that could be regulated by means of an automatic or hand-worked nozzle-spray, according to the weight of inlet air.

Decrease of engine power is further influenced by mechanical efficiency. When the number of revolutions remains constant, the light running work of the engine scarcely diminishes at all, except for its being lessened by the decrease of working pressure, although its proportion to the brake power increases with altitude.

The future alone can show to what extent the altitude power of the normal Daimler engine may be improved by other carburetors, or how closely such decrease would approach a proportional decrease of pressure.

By way of comparison, the power curves of the Maybach Mb IVa and Mb H S Lu engines with 1450 r.p.m. are plotted in terms of altitude in Fig. 5, on the basis of measurements previously taken at the Zeppelin Works. In Fig. 2, the values are also inscribed in Curves 3 and 4. In Fig. 5, Curves 1 to 3 relate to the Mb IVa engine, as follows: Curves 1 with light gasoline power ( $\gamma = 0.708$ ), Curves 2 working with heavy gasoline ( $\gamma = 0.750$ ) and Curves 3 to benzol power, in which case the carburetor might remain constantly open. Curves 4 refer to the Mb H S Lu engine with light gasoline power. In Fig. 2, Curve 3 relates to the Mb IVa engine, and Curve 4 to the Mb H S Lu engine.

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\* "Technische Berichte," Vol. II, No. 1; "The Decrease of Engine Power with Altitude," by H. C. Bader.



### III. THE ENGINE WITH DECREASING OUTSIDE TEMPERATURE AND CONSTANT PRESSURE IN FRONT OF THE CARBURETOR.

These tests constitute a series preparatory to the working of the engine with compressors. Fresh air was inducted to the carburetor by outside piping instead of being admitted through a blower. The air pressure was therefore constant, while the pressure in the experimental chamber and the exhaust back pressure were capable of being regulated. The fuel tank and the float chamber were connected with the air passage of the carburetor by a pipe about 6 mm. in diameter. A receptacle containing about 1/2 liter was attached to the overflow pipe of the float, and fitted with a pet cock through which the overflow gasoline was drawn off. A cowl that can be screwed and unscrewed was fitted on the outlet of the float needle, and the valve spindle of the mixing throttle was made taut by means of a leather washer. The air is admitted directly under the carburetor in order to avoid its being heated by the crankcase. The air passage is not taut, however, as it communicates with the interior of the crankcase through the oil vapor exhaust ports. Air cooling being impossible on account of limited space, water was sprayed into the air passage to cool the crankcase.

These preparations were so adjusted practically that the engine worked satisfactorily from the commencement of the tests onwards. When there was depression in the chamber, fresh air could be let in, and the pressure gradually raised in front of the carburetor, by means of a valve located in the air passage leading to the carburetor. The engine showed no disturbance with abrupt increase of pressure, nor with gradual increase, such change being marked only by an increase in the number of revolutions; that is, by increased power. The mean pressure in front of the carburetor was about 720 mm. (Friedrichshafen is situated at an altitude of about 400 m., mean barometric pressure 730 mm.) 1280 HP was the maximum brake power attained at an altitude of 4000 m. (see Table 3). The main object of this test was that of investigating the behavior of the engine and of the fuel supply with super-pressure.

### IV. ENGINE WITH BLOWER.

A turbo-compressor was attached to the outlet airpipe. A detailed description of this compressor will be given later on. It was driven by a D II-engine, 120 HP, and it compressed 5200 kg. per hour with a total compression ratio of 1.75, corresponding to the quantity of air required by four 260 HP engines with a maximum of 1600 r.p.m., and by the turbo-engine. The compression ratio of 1.75 should be effected as soon as the airplane has reached an altitude of 4500 to 4800 m. and when the compression in front of the carburetor amounts to 1° constant absolute temperature. Only one engine being attached at the tests, and the blower being located outside the vacuum chamber, the compression ratio was obtained by throttles in the intake pipes.

In these tests, too, the working was faultless from the beginning so far as the combined working of engine and blower were concerned. The results of the tests (see Tables 4 and 5) and any statement of conclusions were put off for the time being, until a clear understanding could be ar-



rived at on certain points. The power of an engine may be influenced in so many different ways that it is extremely difficult to distinguish single influences. In addition to the effect of the mixing temperature, heat of the cooling water, etc., the effect of the difference between the intake and exhaust back pressure must also be taken into account. During the compression of the blower, the engine functions in this case as a compressed air engine and the compression work of the blower is regained, the exhaust back pressure diminishing with altitude, so that the useful diagram surface is notably enlarged. At the same time, the exhaust back pressure is proportionally lessened. The cylinder efficiency is improved, and a sort of scavenging is obtained when the openings of the exhaust and inlet valves coincide.

All these conditions must necessarily bring about the increase of engine power with altitude.

An investigation was made of the manner in which the Daimler engine works when charged with fresh air, of its overload capacity, and also of the possibility of finding some substitute for the adjustable bladed propeller in the constant power engine.

The writer has proposed that propellers specially constructed for mean altitudes and for the atmospheric conditions and flying speeds therein prevailing should be used instead of adjustable bladed propellers. Larger pitch, and also, when it is possible, larger diameter, is thus obtained for the propellers than in the case of ordinary propellers with similar power. It is a known fact, however, that the power absorbed by the propeller varies with the third power of the number of revolutions, while the power of the engine varies, in the proximity of the maximum, with the first power of the number of revolutions.

In order to obtain constant power from a propeller in the region of 0 to 5000 m. altitude, the number of revolutions of the engine must therefore be altered from about 10% below the average to 10% above it. To obtain total power from the engine with this diminished number of revolutions, the blower must supply higher pressure, and a greater mixed charge must be injected through the blower.

Fig. 6 shows the course of curves of power, torque and consumption of the Daimler 260 HP engine for three different admission temperatures, pressures  $b$ , and exhaust back-pressures  $p_a$  in front of the carburetor. The values of Curves 1 are as follows:  $b = 830$  mm. mercury,  $p_a = 736$  mm. mercury,  $t \approx 40^\circ$  C; Curves 2:  $b = 760$  mm. mercury,  $p_a = 736$  mm. mercury,  $t \approx 30^\circ$ ; and Curves 3:  $b = 720$  mm. mercury,  $p_a = 728$  mm. mercury,  $t \approx 8^\circ$ . This shows that low compression suffices to produce considerable increase of power, so that increased torque can be realized without difficulty, with the reduced number of revolutions. There were no cases of breakdown, even with frequently repeated overloading, nor were there any sparking plug breakages observed, as in the case of super-compressed engines. The work of the engine was somewhat hard with powers of 300 to 320 HP, but there was no disturbance even with a duration test of half an hour.

Its capacity for overloading is of special advantage at starting in



the case of heavily loaded aircraft or when there is a short starting run. The duration of overloading is a short one in both cases, and no danger is incurred, in consequence, by the engine.

The question of temperature is particularly important when working with compressors. The compression and internal losses (friction and leakages in the blower) are mostly converted into heat, so that the air is consequently more or less heated in proportion to the compression ratio. If fresh air is supplied through a blower driven separately, the pressure corresponding to the altitude of the time being must be produced by altering by hand the number of revolutions of the blowing engine. The highest compression ratio is then required at the highest altitude, and generally when the temperature of the air is lowest. The temperature of the air in front of the carburetor thus remains within acceptable limits. This is not the case for compressors coupled to the main engine or to the central gear, because the compressor always revolves at the same multiple of the number of revolutions of the engine. The pressures produced are therefore too high for the lower flying altitudes, and must consequently be throttled. As the highest temperatures generally prevail at these low altitudes, the compressed air reaches the air in a strongly overheated condition at low altitudes. It may be necessary, in such cases, to insert air-coolers between the compressor and the engine. The gain in power resulting from such cooling may be considerable, as has been seen from tests. Less stress is also put upon the cylinder, when better cylinder charging is effected by cooling, than by increase of pressure.

SUMMARY. Reports of tests of a Daimler IVa engine at the test-bench at Friedrichshafen, show that the decrease of power of that engine, at high altitudes, was established, and that the manner of its working when air is supplied at a certain pressure was explained. These tests were preparatory to the installation of compressors in giant aircraft for the purpose of maintaining constant power at high altitudes.

SUPPLEMENTARY NOTE. While the above report was in the Press, the Zeppelin Works made further tests with regard to the dependence of engine power on the temperature of the air, at different pressures in front of the carburetor, and valuable figures were thereby obtained. The results are collectively stated in Table 6, (tests Nos 150 to 158). In Fig. 7, those values are given with those of earlier tests. The numbers inscribed in the figure refer to the number of the test: Curve 1 to 730, Curve 2 to 760, and Curve 3 to 777 mm. mercury absolute in front of the carburetor. In all three cases, the exhaust back pressure amounted to 730 mm. mercury. Straight line 4 shows what the curve of power would be if it decreased in proportion to the increase of temperature.

Since that time, the first flying tests have also been made with a giant airplane of the Staaken type, with four D IVa engines, equipped with a compressor. The airplane attained almost 6000 m. on that occasion, as compared to its previous maximum altitude of less than 4000 m.



TABLE I.

D I V A ENGINE: FRESH AIR INDUCTED THROUGH AIR PASSAGE OF CRANKCASE.

| Tests: | Alti-  | Barom- | Room           | n       | Brake: | Brake: | Temp-   | Fuel consumption. |        |          | Air               |
|--------|--------|--------|----------------|---------|--------|--------|---------|-------------------|--------|----------|-------------------|
|        | tude.  | eter   | tempera-       |         | load:  | H.P.   | era-    | 4 l.              | =2.83  |          |                   |
|        |        | read-  | ture           |         |        |        | ture    | kg.               |        |          | Density.          |
|        |        | ing.   |                |         |        |        | of      |                   |        |          |                   |
|        |        |        |                |         |        |        | cooled: |                   |        |          |                   |
|        |        |        |                |         |        |        | water:  |                   |        |          |                   |
| No.    | m.     | mm.    | t <sub>o</sub> | R.P.M./ | kg.    | HP     | °C.     | consumed in:      | kg/hr. | g/HP/hr. | kg/m <sup>3</sup> |
|        |        | Q.-S.  | °C.            | min.    |        |        |         |                   |        |          |                   |
| 1      | : 400  | : 726  | : 16           | : 1450  | : 171  | : 249  | : 57    | : 2'57"           | : 57.6 | : 231    | : 1.165           |
| 2      | : 1000 | : 672  | : 17.2         | : 1450  | : 159  | : 232  | : 61    | :                 | :      | :        | : 1.075           |
| 3      | : 1000 | : 672  | : 17.2         | : 1450  | : 157  | : 228  | : 59    | : 2'59"           | : 56.8 | : 249    | : 1.075           |
| 4      | : 2000 | : 595  | : 16.5         | : 1450  | : 138  | : 200  | :       | : 3'10"           | : 53.6 | : 268    | : 0.955           |
| 5      | : 2500 | : 560  | : 19           | : 1450  | : 128  | : 186  | : 72    | : 3'15.6"         | : 52   | : 279    | : 0.89            |
| 6      | : 3000 | : 526  | : 17.8         | : 1450  | : 118  | : 171  | : 71    | : 3'24.2"         | : 49.8 | : 285    | : 0.84            |
| 7      | : 3000 | : 527  | : 19.5         | : 1550  | : 114  | : 178  | : 73    | : 3'12.6"         | : 52.8 | : 296    | : 0.838           |
| 8      | : 3000 | : 527  | : 20           | : 1550  | : 113  | : 175  | :       | :                 | :      | :        | : 0.836           |
| 9      | : 3700 | : 482  | : 18.2         | : 1450  | : 105  | : 152  | : 66    | : 3'31"           | : 48.4 | : 318    | : 0.77            |
| 10     | : 3700 | : 482  | : 18.5         | : 1550  | : 99   | : 154  | :       | : 3'25"           | : 50   | : 325    | : 0.769           |
| 11     | : 4500 | : 435  | : 18.6         | : 1450  | : 90   | : 131  | : 72    | : 3'41.8"         | : 46   | : 350    | : 0.694           |
| 12     | : 4500 | : 436  | : 18.7         | : 1550  | : 85   | : 132  | : 68    | : 3'36"           | : 47.2 | : 357    | : 0.696           |
| 13     | : 5200 | : 400  | : 18.3         | : 1450  | : 76   | : 110  | : 68    | : 3'56.6"         | : 43.2 | : 392    | : 0.64            |
| 14     | : 5200 | : 400  | : 18.4         | : 1550  | : 70   | : 108  | :       | : 3'45.6"         | : 45   | : 416    | : 0.639           |
| 15     | : 6000 | : 361  | : 17.5         | : 1450  | : 51   | : 74   | : 61    | :                 | : 41   | : 555    | : 0.578           |
| 16     | : 6000 | : 361  | : 18.3         | : 1550  | : 46   | : 72   | : 56    | :                 | :      | :        | : 0.577           |



TABLE II.

D IVa ENGINE: FRESH AIR DIRECTLY INJECTED INTO THE CARBURETOR.

| Tests: | Vacuum chamber |                                |                               | Carburetor.                            |                       |                       |                 |               |               | Fuel consumption.                              |          |                  | Air           |                   |
|--------|----------------|--------------------------------|-------------------------------|----------------------------------------|-----------------------|-----------------------|-----------------|---------------|---------------|------------------------------------------------|----------|------------------|---------------|-------------------|
|        | Alti-<br>tude  | Barom-<br>eter<br>read-<br>ing | Room<br>Temp-<br>era-<br>ture | Differ-<br>ence<br>of<br>pres-<br>sure | Abs.<br>pres-<br>sure | Temp-<br>era-<br>ture | n               | Brake<br>load | Brake<br>H.P. | Temp-<br>era-<br>ture<br>of<br>cooled<br>water | 3 l.     | consum-<br>ed in | densi-<br>ty. |                   |
| No.    | m.             | mm.<br>Q.-S.                   | °C.                           | mm.<br>Q.-S.                           | mm.<br>Q.-S.          | °C.                   | r.p.m.<br>/min. | kg.           | H.P.          | °C.                                            |          | kg/hr            | g/HP/<br>hr.  | kg/m <sup>3</sup> |
| 140    | 400            | 730                            | 14                            | --                                     | 730                   | 14                    | 1450            | 179           | 259           | 60                                             | 2' 12"   | 54.7             | 211           | 1.18              |
| 141    | 400            | 730                            | 14                            | --                                     | 730                   | 13                    | 1450            | 179           | 259           | 56                                             | 2' 9"    | 55.7             | 215           | 1.185             |
| 142    | 2000           | 602                            | 14                            | --                                     | 602                   | 14                    | 1450            | 149           | 216           | 48                                             | :        | :                | :             | 0.976             |
| 143    | 2000           | 602                            | 13                            | --                                     | 602                   | 14                    | 1450            | 149           | 216           | 53                                             | 2' 21"   | 51.0             | 236           | 0.975             |
| 144    | 4000           | 471                            | 13                            | --                                     | 471                   | 14                    | 1450            | 112           | 162           | 58                                             | 2' 42.8" | 44.1             | 272           | 0.764             |
| 145    | 4000           | 471                            | 13                            | --                                     | 471                   | 14                    | 1450            | 112           | 162           | 57                                             | 2' 39.6" | 45.1             | 278           | 0.764             |
| 146    | 5000           | 414                            | 13                            | --                                     | 414                   | 13                    | 1450            | 96            | 139           | 55                                             | 2' 53"   | 41.6             | 299           | 0.674             |
| 147    | 5500           | 389                            | 13                            | --                                     | 389                   | 13                    | 1450            | 87            | 126           | 53                                             | 3' 3.2"  | 39.3             | 312           | 0.632             |
| 148    | 5800           | 378                            | 12                            | --                                     | 378                   | 12                    | 1450            | 82            | 119           | :                                              | :        | :                | :             | 0.616             |
| 149    | 6000           | 365                            | 12                            | --                                     | 365                   | 12                    | 1450            | 75            | 109           | 62                                             | 3' 2.5"  | 36.8             | 337           | 0.595             |



TABLE III.

WILLYS ENGINE AT DECREASING ATMOSPHERIC PRESSURE AND VARIOUS PRESSURES  
BEFORE THE CARBURETOR.

| Tests | Vacuum chamber |                                |                                     | Carburetor.                            |                       |                       | n             | Brake<br>load | Brake<br>H.P. | Temp-<br>era-<br>ture<br>of<br>cooled<br>water | Fuel consumption. |       |              | Air<br>densi-<br>ty. |
|-------|----------------|--------------------------------|-------------------------------------|----------------------------------------|-----------------------|-----------------------|---------------|---------------|---------------|------------------------------------------------|-------------------|-------|--------------|----------------------|
|       | Alti-<br>tude  | Barom-<br>eter<br>read-<br>ing | Room<br>temp-<br>era-<br>ture<br>to | Differ-<br>ence<br>of<br>pres-<br>sure | Abs.<br>pres-<br>sure | Temp-<br>era-<br>ture |               |               |               |                                                | consum-<br>ed in  | kg/hr | g/HP/<br>hr. |                      |
| No.   | m.             | Q.-S.                          | °C.                                 | Q.-S.                                  | Q.-S.                 | °C.                   | /min.         | kg.           | H.P.          | °C.                                            |                   |       |              | kg/m <sup>3</sup>    |
| 21    | 400            | 731                            |                                     | -8                                     | 723                   | 9.2                   | 1450          | 169           | 245           | 63                                             | 3' 7.6"           | 57.5  | 235          | 1.191                |
| 22    | 1500           | 626                            |                                     | -6                                     | 620                   | 8.2                   | 1450          | 152           | 220           | 54                                             | 3' 24.6"          | 52.6  | 239          | 1.024                |
| 41    | 1500           | 626                            |                                     | +8.4                                   | 634.4                 | 8.2                   | 1450/<br>1480 | 167           | 244           |                                                |                   |       |              | 1.048                |
| 23    | 400            | 730                            | 10                                  | -6                                     | 724                   | 8.2                   | 1450/<br>1480 | 169           | 246           | 51                                             | 3' 5"             | 58.4  | 237          | 1.195                |
| 24    | 400            | 730                            |                                     | -7                                     | 723                   | 8.2                   | 1450          | 171           | 250           |                                                |                   |       |              | 1.194                |
| 42    | 2000           | 602                            |                                     |                                        |                       |                       | 1450          | 146           | 212           |                                                |                   |       |              |                      |
| 43    | 2000           | 600                            |                                     | +12                                    | 612                   | 8.5                   | 1450          | 151           | 220           |                                                |                   |       |              | 1.012                |
| 44    | 1900           | 608                            |                                     | { +118<br>(+120)                       | 726                   | 9                     | 1450          | 177           | 256           |                                                |                   |       |              | 1.195                |
| 25    | 2600           | 545                            |                                     | +0                                     | 545                   | 9                     |               |               |               |                                                |                   |       |              | 0.898                |
| 26    | 400            | 729.5                          | 8.5                                 | -6                                     | 723.5                 | 8                     | 1450          | 171           | 248           | 49                                             |                   |       |              | 1.195                |
| 27    | 400            | 730                            |                                     | -5                                     | 725                   | 9                     | 1450          | 176           | 255           |                                                | 3' 5.4"           | 58.4  | 229          | 1.195                |
| 28    | 1650           | 625                            | 10.5                                | +2                                     | 627                   | 10                    | 1450          | 156           | 226           | 69                                             | 3' 22"            | 53.5  | 237          | 1.030                |
| 45    | 1720           | 618                            | 11.5                                | +9.8                                   | 627.8                 | 10.2                  | 1450          | 182           | 265           |                                                |                   |       |              | 1.029                |
| 46    | 1720           | 618                            |                                     | +104                                   | 722                   | 10.5                  | 1480          | 178           | 260           |                                                |                   |       |              | 1.183                |
| 29    | 3000           | 530                            | 13                                  | +0                                     | 530                   | 10.8                  | 1450          | 132           | 191           | 52                                             |                   |       |              | 0.868                |
| 47    | 3000           | 530                            | 13                                  | { +198<br>(+195)                       | 728                   | 11                    | 1450          | 177           | 258           | 63                                             |                   |       |              | 1.192                |
| 30    | 3960           | 469                            | 11                                  | -3                                     | 466                   | 11                    | 1450          | 113           | 165           | 61                                             |                   |       |              | 0.769                |



TABLE III (Contd.)

D IVa ENGINE: AT DECREASING ATMOSPHERIC PRESSURE AND VARIOUS PRESSURES BEFORE THE CARBURETOR.

| BEFORE THE CARBURETOR. |               |                                |                                                  |                                        |                       |                       |                 |                   |               |                                                |                  |              |                   |
|------------------------|---------------|--------------------------------|--------------------------------------------------|----------------------------------------|-----------------------|-----------------------|-----------------|-------------------|---------------|------------------------------------------------|------------------|--------------|-------------------|
| Vacuum chamber         |               |                                |                                                  | Carburetor.                            |                       |                       |                 | Fuel consumption. |               |                                                |                  |              |                   |
| Tests                  | Alti-<br>tude | Barom-<br>eter<br>read-<br>ing | Room-<br>tem-<br>pera-<br>ture<br>t <sub>o</sub> | Differ-<br>ence<br>of<br>pres-<br>sure | Abs.<br>pres-<br>sure | Temp-<br>era-<br>ture | n               | Brake<br>load     | Brake<br>H.P. | Temp-<br>era-<br>ture<br>of<br>cooled<br>water | Air<br>density   |              |                   |
| No.                    | m.            | mm.<br>Q.-S.                   | °C.<br>Q.-S.                                     | mm.<br>Q.-S.                           | mm.<br>Q.-S.          | °C.                   | r.p.m.<br>/min. | kg.               | H.P.          | °C.                                            | consum-<br>ed in | g/HP/<br>hr. | kg/m <sup>3</sup> |
| 48                     | :4000         | :468                           | :14                                              | :+257                                  | :725                  | :10.8                 | :1450           | :175              | :254          | :62                                            | :                | :            | :1.188            |
| 49                     | :5000         | :410                           | :14.5                                            | :+12                                   | :422                  | :11                   | :1450           | :102              | :148          | :62                                            | :                | :            | :0.692            |
| 50                     | :5000         | :410                           | :                                                | :+312                                  | :722                  | :                     | :1450           | :                 | :             | :                                              | :                | :            | :                 |
| 31                     | :400          | :729                           | :6.5                                             | : -5                                   | :724                  | : -1                  | :1450           | :172              | :250          | :47                                            | :62.8            | :251         | :1.238            |
| 51                     | :1950         | :604                           | :8.5                                             | :+5                                    | :609                  | ±0                    | :1450           | :152              | :221          | :49                                            | :57.6            | :261         | :1.037            |
| 52                     | :1920         | :602                           | :8.5                                             | :+118                                  | :720                  | : -0.3                | :1450           | :187              | :271          | :53                                            | :63.5            | :234         | :1.228            |
| 53                     | :3000         | :528                           | :8.5                                             | :+7                                    | :535                  | : -0.8                | :1450           | :132              | :191          | :50                                            | :53.6            | :281         | :0.914            |
| 54                     | :3000         | :526                           | :8.5                                             | :+193                                  | :719                  | ±0                    | :1450           | :187              | :271          | :51                                            | :63.4            | :234         | :1.225            |
| 32                     | :4060         | :462                           | :9                                               | : -7                                   | :455                  | ±0                    | :1450           | :109              | :159          | :46                                            | :50.5            | :318         | :0.775            |
| 55                     | :4080         | :460                           | :11                                              | :+258                                  | :718                  | ±0                    | :1450           | :189              | :275          | :53                                            | :63              | :229         | :1.222            |
| 33                     | :400          | :727                           | :8.5                                             | : -7                                   | :720                  | :3.6                  | :1450           | :172              | :249          | :46                                            | :                | :            | :1.210            |
| 34                     | :6000         | :362                           | :11                                              | :+2                                    | :364                  | :4.8                  | :1450           | :83               | :120          | :48                                            | :                | :            | :0.606            |
| 56                     | :4500         | :440                           | :15                                              | :+275                                  | :715                  | :4.8                  | :1450           | :177              | :256          | :65                                            | :64.5            | :252         | :1.196            |
| 35                     | :4000         | :464                           | :14.5                                            | :+1                                    | :465                  | :5.2                  | :1450           | :115              | :167          | :53                                            | :                | :            | :0.778            |
| 57                     | :4000         | :464                           | :15.5                                            | :+249                                  | :713                  | :4.8                  | :1450           | :193              | :280          | :                                              | :                | :            | :1.193            |



TABLE IV.

D IVA ENGINE WITH BLOWER.

| D IVA ENGINE WITH BLOWER. |                |                |                              |                 |                 |           |            |            |                                   |                     |                  |             |               |                  |                    |       |
|---------------------------|----------------|----------------|------------------------------|-----------------|-----------------|-----------|------------|------------|-----------------------------------|---------------------|------------------|-------------|---------------|------------------|--------------------|-------|
| Tests:                    | Vacuum chamber |                | Before the carburetor.       |                 |                 |           |            |            |                                   |                     | Fuel consumption |             | Blower        |                  | Air dens-ity.      |       |
|                           | Alti- tude     | eter read- ing | Dif- fer- ence of pres- sure | Abs. pres- sure | Temp- era- ture | n         | Brake load | Brake H.P. | Temp- era- ture of cool- ed water | 2 kg. consum- ed in |                  | Pressure at | In- take tube | Dis- charge tube |                    |       |
| No.                       | m.             | mm. Q.-S.      | mm. Q.-S.                    | mm. Q.-S.       | °C.             | rpm/ min. | kg         | H.P.       | °C.                               | kg/ hr.             | g/ hp/ min.      | rpm/ min.   | mm. Q.-S.     | mm. Q.-S.        | kg/ m <sup>3</sup> |       |
| 61                        | :              | 729            | -5                           | 724             | + 9             | 1450      | 176        | 255        | :                                 | :                   | :                | :           | :             | :                | 1.192              |       |
| 62                        | :              | 729            | +5                           | 734             | +26.5           | 1450      | 182        | 264        | :                                 | :                   | :                | :           | 600           | -115             | + 10               | 1.14  |
| 63                        | :              | 729            | +0                           | 729             | +38             | 1450      | 177        | 257        | :                                 | :                   | :                | :           | 980           | -145             | + 6                | 1.088 |
| 64                        | :              | 729            | -2                           | 727             | +61.5           | 1450      | 169        | 245        | :                                 | :                   | :                | :           | 1360          | -255             | + 4                | 1.015 |
| 65                        | :              | 729            | +0                           | 729             | +74.5           | 1450      | 165        | 239        | :                                 | :                   | :                | :           | 1450          | -275             | + 4                | 0.975 |
| 66                        | :              | 729            | -12                          | 717             | + 4             | 1450      | 173        | 251        | :                                 | :                   | :                | :           | :             | :                | :                  | 1.20  |
| 67                        | :              | 729            | +12                          | 741             | +11.5           | 1450      | 184        | 267        | :                                 | :                   | :                | :           | :             | :                | + 16               | 1.21  |
| 68                        | :              | 729            | +28                          | 757             | +12             | 1450      | 189        | 275        | :                                 | :                   | :                | :           | :             | :                | + 30               | 1.235 |
| 69                        | :              | 729            | +54                          | 784             | +14.5           | 1450      | 192        | 279        | :                                 | :                   | :                | :           | :             | :                | + 64               | 1.265 |
| 70                        | 400            | 724            | -4                           | 720             | + 1             | 1450      | 174        | 252        | :                                 | :                   | :                | :           | :             | :                | :                  | 1.22  |
| 71                        | 400            | 724            | +16                          | 740             | +11             | 1450      | 182        | 264        | :                                 | :                   | :                | :           | :             | :                | :                  | 1.21  |
| 72                        | 400            | 722            | +42                          | 764             | +16.5           | 1450      | 192        | 278        | :                                 | :                   | :                | :           | :             | :                | :                  | 1.23  |
| 73                        | 400            | 722            | +14                          | 736             | +11             | 1450      | 182        | 264        | :                                 | :                   | :                | :           | :             | :                | :                  | 1.205 |
| 74                        | 1000           | 670            | +72                          | 742             | +12             | 1450      | 189        | 274        | :                                 | :                   | :                | :           | :             | :                | :                  | 1.21  |
| 75                        | 400            | 736            | +28                          | 764             | +17             | 1450      | 192        | 279        | 44                                | 1'56.2"             | 62               | 222         | -5            | + 30             | :                  | 1.22  |
| 76                        | 1000           | 683            | +77                          | 760             | +25.5           | 1450      | 196        | 284        | 47                                | 1'53.6"             | 63.3             | 223         | -40           | + 30             | :                  | 1.18  |
| 77                        | 1000           | 683            | +92                          | 775             | +33             | 1450      | 191        | 277        | 44                                | 1'53.3"             | 63.5             | 229         | -100          | + 45             | :                  | 1.175 |
| 78                        | 1000           | 683            | +105                         | 788             | +48             | 1450      | 191        | 277        | 50                                | 1'52.4"             | 64               | 231         | -150          | + 60             | :                  | 1.14  |
| 79                        | 1000           | 683            | +80                          | 763             | +56.5           | 1450      | 176        | 255        | 44                                | 1'55"               | 65               | 245         | +200          | + 30             | :                  | 1.075 |
| 80                        | 400            | 735            | +28                          | 763             | +27             | 1450      | 192        | 279        | 53                                | 1'58.8"             | 60.5             | 217         | -18           | + 20             | :                  | 1.18  |
| 81                        | 400            | 730            | +32                          | 762             | +21             | 1450      | 189        | 274        | 50                                | 1'50"               | 64.9             | 237         | --            | --               | :                  | 1.205 |



TABLE IV (Contd.)

D IV<sup>2</sup> ENGINE WITH BLOWER.

| Tests: | Vacuum chamber: |                      | Before the carburetor                       |                       | Temp-<br>era-<br>ture<br>of<br>cool-<br>ed<br>water: | Brake<br>load: | Brake<br>H.P.: | Fuel consumption:          |                  |            | Blower     |              |                                       |                        |                                               |                       |
|--------|-----------------|----------------------|---------------------------------------------|-----------------------|------------------------------------------------------|----------------|----------------|----------------------------|------------------|------------|------------|--------------|---------------------------------------|------------------------|-----------------------------------------------|-----------------------|
|        | Alti-<br>tude   | eter<br>read-<br>ing | Dif-<br>fer-<br>ence<br>of<br>pres-<br>sure | Abs.<br>pres-<br>sure |                                                      |                |                | Temp-<br>era-<br>ture<br>n | consum-<br>ed in | kg/<br>hr. | hp/<br>hr. | rpm/<br>min: | Pressure<br>at<br>In-<br>take<br>tube | Dis-<br>charge<br>tube | Air<br>den-<br>sity.<br>kg/<br>m <sup>3</sup> |                       |
| No.    | m.              | mm.<br>Q.S.          | mm.<br>Q.S.                                 | mm.<br>Q.S.           | °C.                                                  | rpm/<br>min:   | kg.            | H.P.                       | °C.              | ed in      | kg/<br>hr. | hp/<br>hr.   | rpm/<br>min:                          | mm.<br>Q.S.            | mm.<br>Q.S.                                   | kg/<br>m <sup>3</sup> |
| 82     | : 400           | : 732                | : +27                                       | : 759                 | : +21                                                | : 1450         | : 187          | : 271                      | : 47             | : 1'55"    | : 62.6     | : 231        | :                                     | : -57                  | : +32                                         | : 1.200               |
| 83     | : 1000          | : 680                | : +78                                       | : 758                 | : +29                                                | : 1450         | : 189          | : 274                      | : 61             | : 1'58"    | : 61.1     | : 223        | :                                     | : -57                  | : +32                                         | : 1.165               |
| 84     | : 1000          | : 680                | : +83                                       | : 763                 | : +32.5                                              | : 1450         | : 187          | : 271                      | : 50             | : 1'57"    | : 61.5     | : 227        | :                                     | : -60                  | : +32                                         | : 1.162               |
| 85     | : 1000          | : 680                | : +96                                       | : 776                 | : +42                                                | : 1450         | : 192          | : 278                      | : 62             | : 1'52.5"  | : 63.9     | : 230        | :                                     | : -52                  | : +50                                         | : 1.145               |
| 86     | : 1000          | : 680                | : +125                                      | : 805                 | : +49                                                | : 1450         | : 197          | : 286                      | : --             | : 1'52.5"  | : 64       | : 224        | :                                     | : -52                  | : +75                                         | : 1.160               |
| 87     | : 400           | : 736                | : +27                                       | : 763                 | : +18                                                | : 1450         | : 189          | : 274                      | : 52             | : 1'59.6"  | : 60.3     | : 220        | :                                     | : --                   | : --                                          | : 1.21                |
| 88     | : 2000          | : 605                | : +160                                      | : 765                 | : +42                                                | : 1450         | : 190          | : 275                      | : 45             | : 1'53.4"  | : 63.5     | : 231        | :                                     | : -150                 | : +30                                         | : 1.13                |
| 89     | : 2000          | : 605                | : +180                                      | : 785                 | : +52                                                | : 1450         | : 197          | : 285                      | : 60             | : 1'52"    | : 64.5     | : 226        | :                                     | : -140                 | : +50                                         | : 1.12                |
| 90     | : 2000          | : 605                | : +205                                      | : 810                 | : +62                                                | : 1450         | : 199          | : 289                      | : 57             | : 1'52"    | : 64.2     | : 222        | :                                     | : -140                 | : +75                                         | : 1.12                |
| 91     | : 3000          | : 534                | : +226                                      | : 760                 | : +79                                                | : 1450         | : 184          | : 267                      | : 51             | : 1'53"    | : 63.5     | : 238        | :                                     | : -205                 | : +30                                         | : 1.00                |
| 92     | : 3000          | : 534                | : +250                                      | : 784                 | : +87                                                | : 1450         | : 185          | : 268                      | : 53             | : 1'52.6"  | : 63.7     | : 238        | :                                     | : -200                 | : +50                                         | : 1.00                |
| 93     | : 3000          | : 534                | : +274                                      | : 808                 | : +87                                                | : 1450         | : 191          | : 277                      | : 53             | : 1'52"    | : 64.3     | : 232        | :                                     | : -205                 | : +75                                         | : 1.04                |
| 94     | : 4000          | : 470                | :                                           | :                     | :                                                    | :              | :              | :                          | :                | :          | :          | :            | :                                     | : -260                 | : -26                                         | :                     |
| 95     | : 2500          | : 500                | : +230                                      | : 730                 | : > 100                                              | : 1450         | : 165          | : 240                      | : 50             | : 2'10"    | : 55.5     | : 231        | :                                     | : -230                 | : +5                                          | : 0.91                |
| 96     | : 2000          | : 602                | : +227                                      | : 829                 | : +76                                                | : 1450         | : 194          | : 281                      | : 58             | : 1'51"    | : 65.0     | : 231        | :                                     | : -130                 | : +100                                        | : 1.10                |
| 97     | : 2000          | : 602                | : +283                                      | : 885                 | : +95                                                | : 1450         | : 190          | : 276                      | : 58             | : 1'53"    | : 63.8     | : 231        | :                                     | : -130                 | : +150                                        | : 1.12                |
| 98     | : 3000          | : 532                | : +290                                      | : 822                 | : > 100                                              | : 1450         | : 180          | : 261                      | : 48             | : 1'50"    | : 65.3     | : 250        | :                                     | : -200                 | : +100                                        | : 1.02                |
| 132    | : 1000          | : 675                | : +48                                       | : 723                 | : +13                                                | : 1450         | : 182          | : 264                      | : 60             | : 2'6"     | : 57.4     | : 217        | :                                     | : -55                  | : +2                                          | : 1.175               |
| 133    | : 3000          | : 527                | : +205                                      | : 732                 | : +54                                                | : 1450         | : 160          | : 232                      | : 65             | : 2'6"     | : 57.0     | : 246        | :                                     | : -210                 | : +0                                          | : 1.04                |
| 134    | : 1300          | : 650                | : +170                                      | : 820                 | : +37                                                | : 1450         | : 221          | : 320                      | : 60             | : 1'57"    | : 61.5     | : 192        | :                                     | : -85                  | : +105                                        | : 1.228               |
| 135    | : 2000          | : 592                | : +130                                      | : 722                 | : +36                                                | : 1450         | : 187          | : 273                      | : 58             | : 2'3.6"   | : 58.2     | : 213        | :                                     | : -130                 | : +5                                          | : 1.086               |
| 136    | : 3500          | : 490                | : +295                                      | : 785                 | : +95                                                | : 1450         | : 185          | : 268                      | : 65             | : 1'53.2"  | : 63.5     | : 237        | :                                     | : -235                 | : +80                                         | : 0.992               |
| 137    | : 4000          | : 462                | : +260                                      | : 722                 | : > 105                                              | : 1450         | : 170          | : 247                      | : 63             | : 1'59"    | : 60.5     | : 245        | :                                     | : -260                 | : +15                                         | : 0.888               |
| 138    | : 4500          | : 434                | : +240                                      | : 674                 | : > 105                                              | : 1450         | : 155          | : 225                      | : 58             | : 2'5"     | : 57.6     | : 256        | :                                     | : -280                 | : -50                                         | : 0.829               |



TABLE V.

DIESEL ENGINE WITH BLOWER.

| Tests:           | Barom-<br>Alti-<br>tude | Dif-<br>eter<br>read-<br>ing | Work-<br>fer-<br>ence<br>of<br>pres-<br>sure | Temp-<br>ing<br>pres-<br>sure<br>ture | n   | Brake<br>load | Brake<br>H.P. | Temp-<br>era-<br>ture<br>of<br>cool-<br>ed<br>water | 2 kg.<br>Con-<br>sumed | g/<br>kg/<br>hr. | Air<br>densi-<br>ty | Calculated<br>performance | torsion<br>moment | Mean<br>work-<br>ing<br>pres-<br>sure |       |      |
|------------------|-------------------------|------------------------------|----------------------------------------------|---------------------------------------|-----|---------------|---------------|-----------------------------------------------------|------------------------|------------------|---------------------|---------------------------|-------------------|---------------------------------------|-------|------|
| No.              | m.                      | mm.<br>Q.-S.                 | mm.<br>Q.-S.                                 | mm.<br>Q.-S.                          | °C. | rpm/<br>min.  | kg.           | H.P.                                                | °C.                    | in               | hr.                 | hr.                       | kg/m <sup>3</sup> | H.P.                                  | cm/kg | at   |
| b = 760 mm Q.-S. |                         |                              |                                              |                                       |     |               |               |                                                     |                        |                  |                     |                           |                   |                                       |       |      |
| 101              | 400                     | 736                          | +22                                          | 758                                   | +22 | 1450          | 187           | 271                                                 | 46                     | 1'59.2"          | 60.7                | 223                       | 1.192             | 272                                   | 13400 | 7.7  |
| 102              | 400                     | 736                          | +26                                          | 762                                   | +23 | 1550          | 182           | 281                                                 | 49                     | 1'51.0"          | 65.0                | 231                       | 1.195             | 280                                   | 12900 | 7.5  |
| 103              | 400                     | 736                          | +34                                          | 770                                   | +26 | 1550          | 186           | 289                                                 | 43                     | 1'54.6"          | 62.7                | 217                       | 1.195             | 285                                   | 13200 | 7.7  |
| 104              | 400                     | 736                          | +33                                          | 769                                   | +26 | 1450          | 191           | 277                                                 | 75                     | 1'56.0"          | 62.0                | 224                       | 1.195             | 274                                   | 13550 | 7.9  |
| 105              | 400                     | 736                          | +26                                          | 762                                   | +25 | 1350          | 192           | 259                                                 | 60                     | 2'14.0"          | 53.6                | 207                       | 1.189             | 258                                   | 13700 | 7.95 |
| 106              | 400                     | 736                          | +26                                          | 762                                   | +25 | 1350          | 192           | 259                                                 | 50                     | 2'7.2"           | 56.7                | 219                       | 1.189             | 258                                   | 13700 | 7.95 |
| 107              | 400                     | 736                          | +25                                          | 761                                   | +23 | 1250          | 195           | 244                                                 | 58                     | 2'27.8"          | 52.5                | 215                       | 1.195             | 244                                   | 14000 | 8.1  |
| 108              | 400                     | 736                          | +26                                          | 762                                   | +24 | 1150          | 197           | 227                                                 | 70                     | 2'17.0"          | 52.4                | 231                       | 1.192             | 226                                   | 14100 | 8.18 |
| 109              | 400                     | 736                          | +25                                          | 761                                   | +23 | 1050          | 195           | 205                                                 | 52                     | 2'46"            | 43.5                | 212                       | 1.195             | 205                                   | 14000 | 8.1  |
| b = 830 mm Q.-S. |                         |                              |                                              |                                       |     |               |               |                                                     |                        |                  |                     |                           |                   |                                       |       |      |
| 110              | 400                     | 736                          | +96                                          | 832                                   | +42 | 1450          | 206           | 299                                                 | 54                     | 1'57.4"          | 61.3                | 205                       | 1.228             | 298                                   | 14750 | 8.55 |
| 111              | 400                     | 736                          | +96                                          | 832                                   | +42 | 1350          | 207           | 279                                                 | 55                     | 1'58"            | 61.1                | 219                       | 1.228             | 278                                   | 14800 | 8.6  |
| 112              | 400                     | 736                          | +94                                          | 830                                   | +40 | 1250          | 211           | 264                                                 | 54                     | 2'11.6"          | 54.6                | 207                       | 1.232             | 264                                   | 15100 | 8.75 |
| 113              | 400                     | 736                          | +96                                          | 832                                   | +38 | 1150          | 214           | 246                                                 | 52                     | 2'24.6"          | 50.0                | 203                       | 1.243             | 245                                   | 15300 | 8.9  |
| 114              | 400                     | 736                          | +92                                          | 828                                   | +36 | 1050          | 210           | 221                                                 | 52                     | 2'31.6"          | 47.5                | 215                       | 1.245             | 222                                   | 15050 | 8.7  |
| 115              | 400                     | 736                          | +92                                          | 828                                   | +40 | 1550          | 203           | 315                                                 | 53                     | 1'53.6"          | 63.5                | 201                       | 1.230             | 316                                   | 14500 | 8.42 |



TABLE V (Cont.)

## D IVA ENGINE WITH BLOWER.

| No.              | Vacuum chamber |                | Before the carburetor.                      |                        |                       |              | Brake load | Brake H.P. | Temp-<br>era-<br>ture<br>of<br>cool-<br>ed<br>water | Fuel consumption |                |             | Air<br>dens-<br>ity | Calculated<br>performance | Torsion<br>moment | Mean<br>work-<br>ing<br>pres-<br>sure |
|------------------|----------------|----------------|---------------------------------------------|------------------------|-----------------------|--------------|------------|------------|-----------------------------------------------------|------------------|----------------|-------------|---------------------|---------------------------|-------------------|---------------------------------------|
|                  | Alti-<br>meter | Barom-<br>eter | Dif-<br>fer-<br>ence<br>of<br>pres-<br>sure | Abs.:<br>pres-<br>sure | Temp-<br>era-<br>ture | n            |            |            |                                                     | 2 kg.            | Con-<br>sumed- | g/<br>H.P./ |                     |                           |                   |                                       |
|                  | m.             | Q.-S.          | mm.                                         | mm.                    | °C.                   | rpm/<br>min. | kg.        | H.P.       | °C.                                                 | in               | hr.            | hr          | kg/m <sup>3</sup>   | H.P.                      | cm/kg             | at                                    |
| b = 720 mm Q.-S. |                |                |                                             |                        |                       |              |            |            |                                                     |                  |                |             |                     |                           |                   |                                       |
| 116              | 400            | 728            | -8                                          | 720                    | +10                   | 1450         | 172        | 250        | 60                                                  | 2' 7.4"          | 56.5           | 226         | 1.181               | 250                       | 12320             | 7.15                                  |
| 117              | 400            | 728            | -8                                          | 720                    | +8                    | 1350         | 157        | 236        | 53                                                  | 2' 22.4"         | 50.7           | 215         | 1.190               | 236                       | 12500             | 7.25                                  |
| 118              | 400            | 728            | -6                                          | 722                    | +7                    | 1150         | 179        | 206        | 65                                                  | 2' 41.6"         | 44.5           | 216         | 1.200               | 205                       | 12800             | 7.40                                  |
| 119              | 400            | 728            | -7                                          | 721                    | +5                    | 1250         | 177        | 221        | 50                                                  | 2' 32"           | 47.4           | 214         | 1.206               | 221                       | 12650             | 7.35                                  |
| 120              | 400            | 728            | -5                                          | 723                    | +5                    | 1050         | 178        | 187        | 55                                                  | 2' 54.6"         | 41.2           | 220         | 1.209               | 186                       | 12730             | 7.4                                   |
| 121              | 400            | 728            | -12                                         | 716                    | +5                    | 1550         | 172        | 267        | 60                                                  | 2' 4.6"          | 57.7           | 216         | 1.197               | 269                       | 12300             | 7.15                                  |
| b = 760 mm Q.-S. |                |                |                                             |                        |                       |              |            |            |                                                     |                  |                |             |                     |                           |                   |                                       |
| 122              | 400            | 732            | +28                                         | 760                    | +17                   | 1450         | 192        | 278        | 52                                                  | 2' 3.4"          | 58             | 209         | 1.218               | 278                       | 13700             | 7.95                                  |
| 123              | 400            | 732            | +29                                         | 761                    | +17                   | 1450         | 192        | 278        | 56                                                  | 2' 2.6"          | 58.6           | 211         | 1.220               | 278                       | 13700             | 7.95                                  |
| 124              | 400            | 732            | +28                                         | 760                    | +17                   | 1350         | 195        | 263        | 60                                                  | 2' 15.3"         | 53.1           | 202         | 1.218               | 263                       | 13950             | 8.1                                   |
| 125              | 400            | 732            | +29                                         | 761                    | +17                   | 1250         | 197        | 246        | 59                                                  | 2' 29.8"         | 48             | 195         | 1.220               | 246                       | 14100             | 8.15                                  |
| 126              | 400            | 732            | +29                                         | 761                    | +16                   | 1150         | 197        | 227        | 59                                                  | 2' 36.8"         | 45.9           | 202         | 1.225               | 227                       | 14100             | 8.15                                  |
| 127              | 400            | 732            | +29                                         | 761                    | +15                   | 1050         | 197        | 207        | 56                                                  | 2' 53"           | 41.6           | 201         | 1.229               | 207                       | 14100             | 8.15                                  |
| 128              | 400            | 732            | +27                                         | 759                    | +17                   | 1550         | 190        | 294        | 60                                                  | 2' 54"           | 62.9           | 214         | 1.217               | 294                       | 13530             | 7.85                                  |
| 129              | 400            | 732            | +48                                         | 780                    | +22                   | 1450         | 200        | 290        | 58                                                  | 2' 6"            | 59.8           | 206         | 1.230               | 282                       | 14300             | 8.3                                   |
| 130              | 400            | 732            | +78                                         | 810                    | +28                   | 1450         | 205        | 297        | 63                                                  | 1' 57.6"         | 61.2           | 206         | 1.250               | 279                       | 14600             | 8.45                                  |
| 131              | 400            | 732            | +165                                        | 897                    | +34                   | 1450         | 224        | 325        | 58                                                  | 1' 57"           | 61.4           | 189         | 1.357               | 275                       | 16000             | 9.25                                  |



TABLE VI.

DIVA ENGINE TEST SHOWING DEPENDENCY OF POWER ON THE TEMPERATURE.

| Tests | Vacuum chamber. |                | Before the carburetor.                |                       |                       |              | Fuel consumption. |               |                       |                       |                        |          |                   |       | Air density. |
|-------|-----------------|----------------|---------------------------------------|-----------------------|-----------------------|--------------|-------------------|---------------|-----------------------|-----------------------|------------------------|----------|-------------------|-------|--------------|
|       | Alti-<br>tude   | Barom-<br>eter | Diff-<br>erence<br>of<br>pres-<br>ure | Abs.<br>pres-<br>sure | Temp-<br>era-<br>ture | rpm/<br>min. | Brake<br>load     | Brake<br>H.P. | Temp-<br>era-<br>ture | Temp-<br>era-<br>ture | 2 kg.<br>Con-<br>sumed | kg/hr    | g/HP/hr.          |       |              |
|       |                 |                |                                       |                       |                       |              |                   |               |                       |                       |                        |          |                   |       |              |
|       |                 |                |                                       |                       |                       |              |                   |               |                       |                       |                        |          |                   |       |              |
| No.   | m.              | mmQ. -S.       | mm. Q. -S.                            | mm. Q. -S.            | °C.                   | min.         | kg.               | HP            | °C.                   | in                    | kg/hr                  | g/HP/hr. | kg/m <sup>3</sup> |       |              |
| 150   | 400             | 734            | +26                                   | 760                   | +22                   | 1450         | 188               | 273           | 47                    | 2'                    | 2.4"                   | 59       | 215               | 1.20  |              |
| 151   | 400             | 734            | 26                                    | 760                   | 38                    | 1450         | 188               | 273           | 52                    | 2'                    | 6.6"                   | 57       | 208               | 1.135 |              |
| 152   | 400             | 734            | 25                                    | 759                   | 66                    | 1450         | 178               | 258           | 55                    | 2'                    | 5.4"                   | 57.5     | 223               | 1.04  |              |
| 153   | 400             | 734            | 26                                    | 760                   | 81                    | 1450         | 173               | 251           | 60                    | 2'                    | 6.2"                   | 57       | 227               | 1.00  |              |
| 154   | 400             | 734            | 26                                    | 760                   | 88                    | 1450         | 171               | 248           | 63                    | 2'                    | 8.0"                   | 56.4     | 227               | 0.98  |              |
| 155   | 400             | 734            | 43                                    | 777                   | 31                    | 1450         | 193               | 280           | 55                    | 2'                    | 4.0"                   | 58       | 207               | 1.19  |              |
| 156   | 400             | 734            | 43                                    | 777                   | 48                    | 1450         | 190               | 275           | 66                    | 2'                    | 4.0"                   | 58       | 211               | 1.13  |              |
| 157   | 400             | 734            | 43                                    | 777                   | 65                    | 1450         | 186               | 269           | 58                    | 2'                    | 6.4"                   | 57       | 212               | 1.07  |              |
| 158   | 400             | 734            | 43                                    | 777                   | 82                    | 1450         | 179               | 259           | 59                    | 2'                    | 6.0"                   | 57       | 221               | 1.02  |              |



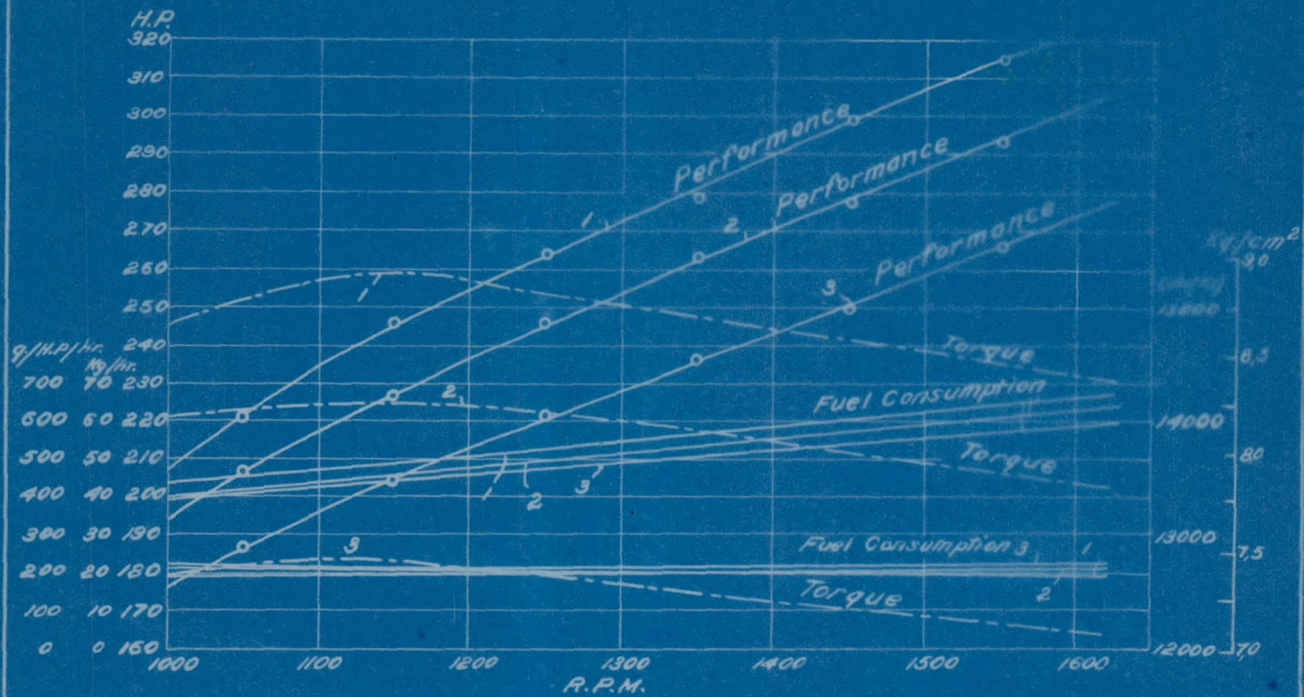


Fig. 6. Performance torque and gas consumption of the D.IV engine for three different intake and exhaust pressures and intake temperatures before the carburetor at increasing engine speeds.

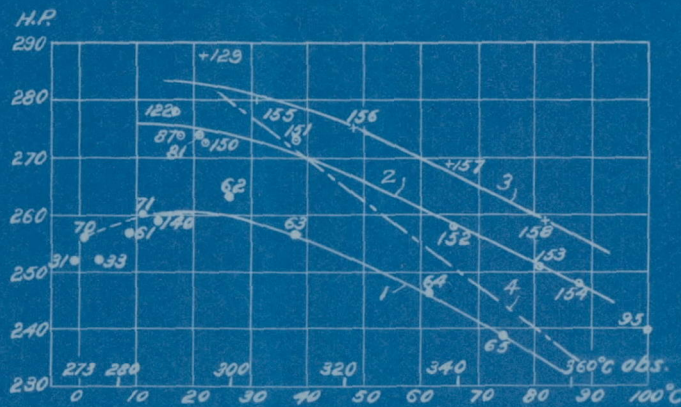


Fig. 7. Dependence of engine performance on intake temperature at 1450 R.P.M. with various pressures before the carburetor and at constant exhaust pressure.



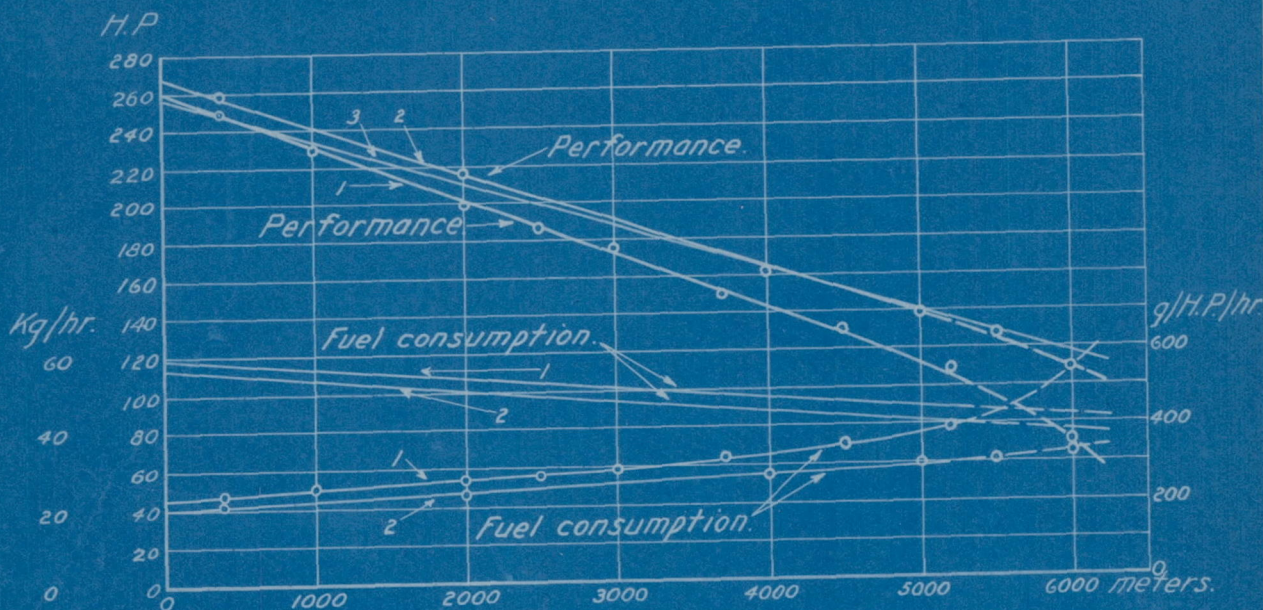


Fig. 1.  
Performance and gas consumption of D IVa engine  
running at 1450 r.p.m. at various  
altitudes.

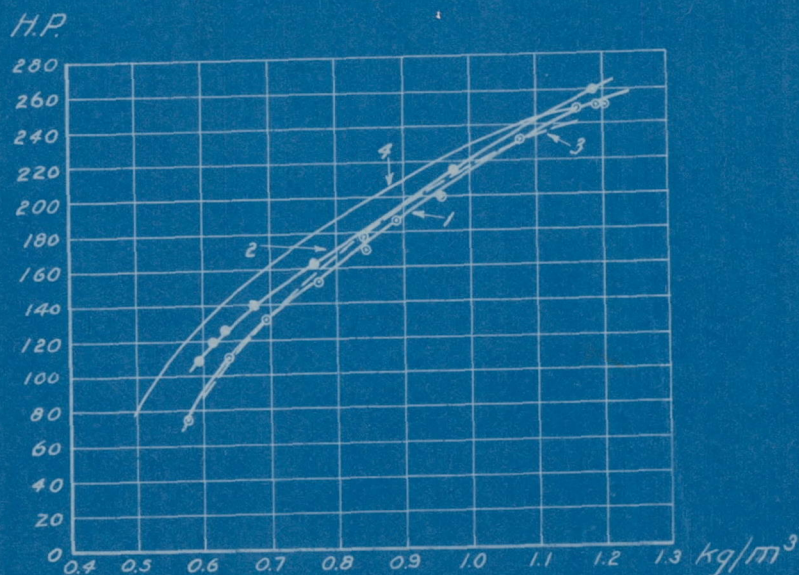


Fig. 2.  
Performance of D IVa engine run-  
ning at 1450 r.p.m. for var-  
ious air densities.



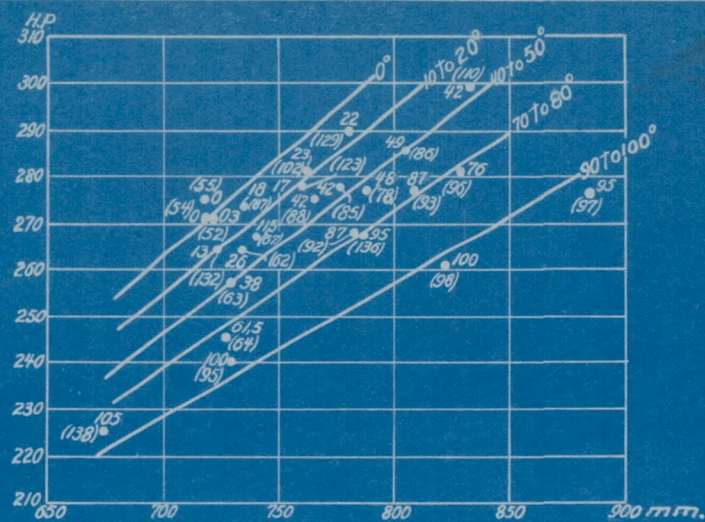


Fig. 3. Dependence of performance on the pressure and temperature of the intake air before the carburetor.

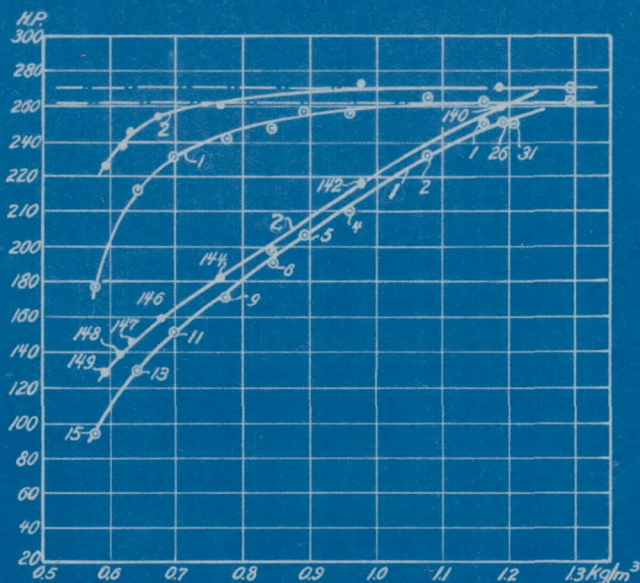


Fig. 4. Calculated performance of DVIIa engine running at 1450 R.P.M. with various air densities.

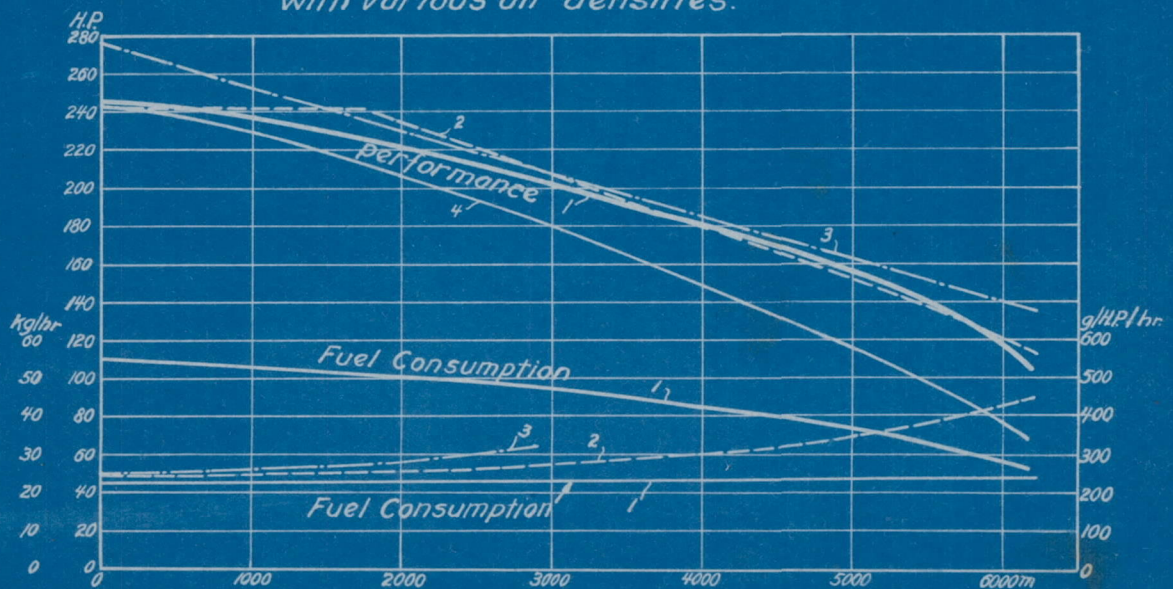


Fig. 5. Performance and gasoline consumption of the MbIVa and the Mb HSLu engines running at 1450 R.P.M. at various altitudes.